Metabolism

Lecture 4

Energy balance & food intake

ILOs

By the end of this lecture the student will be able to:

- Define hunger and satiety
- Describe the nervous regulation of food intake
- Explain the role of different centers involved in food intake
- Explain the role of different neurotransmitters and hormones that influence feeding behavior
- Describe the short term and long term regulation of food intake

Dietary balance

Food intake is essential for life.

It maintains a normal energy balance in the body & body weight constant.

It is regulated by biological control system.

Food intake is controlled by sensation of hunger & appetite.

Hunger: It means the need for food that might be associated with hunger pain (strong rhythmic cont. in the stomach wall).

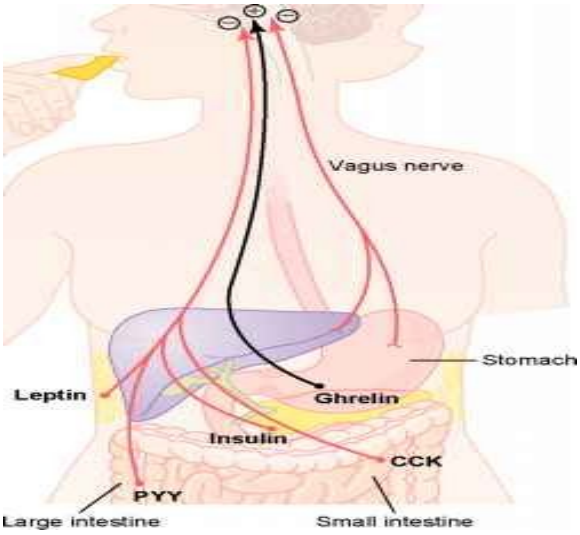
Appetite: It is the desire for specific types of food.

Satiety: Sensation of fulfilment after taking food.

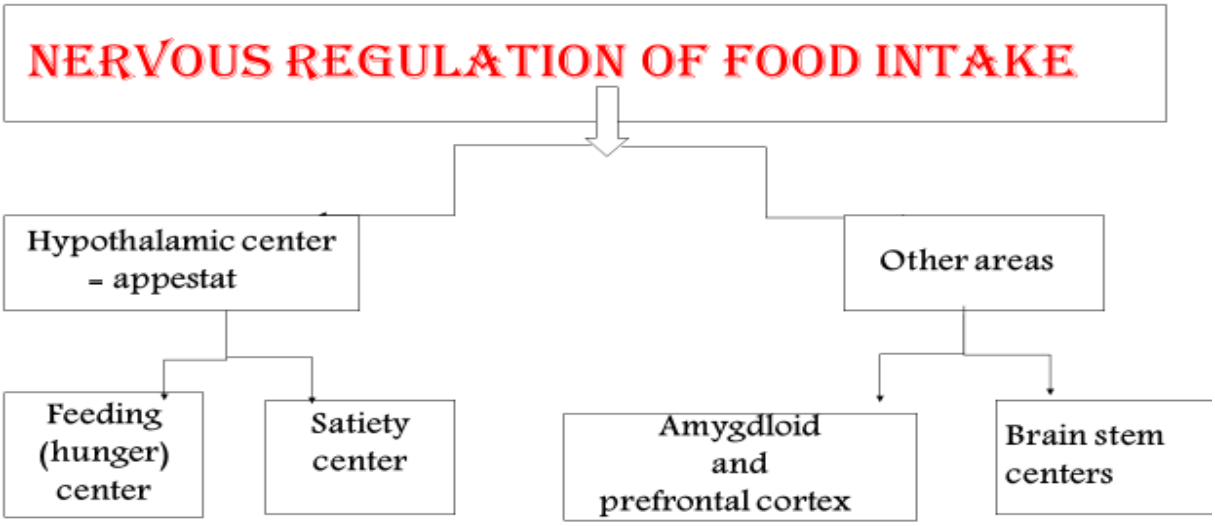
It tell us when we have enough & it operates via inhibition of Feeding Center after food ingestion.

Set point: There is a point for body weight & activity of the hypothalamus to control food intake to keep body weight constant.

Each of feelings (hunger or appetite) is influenced by environmental and cultural factors, as well as by physiologic controls that influence specific centers of the brain, especially the hypothalamus.



The hypothalamus receives neural signals from the **gastrointestinal tract** that provide sensory information about stomach filling, chemical signals from **nutrients** in the blood (glucose, amino acids, and fatty acids) that signify satiety, signals from **gastrointestinal hormones** (ghrelin, CCK, PYY, …), , signals from **hormones released by adipose tissue**, and signals from the **cerebral cortex** (sight, smell, and taste) that influence feeding behavior.



Under normal physiological conditions, appetite and food intake are well balanced and continues in a cyclic manner. These centers are regulated by the following mechanisms:

i. Glucostatic mechanism

ii. Lipostatic mechanism

iii. Peptide mechanism

iv. Hormonal mechanism

v. Thermostatic mechanism

Hypothalamic centers

1- *Feeding center:*

Site: lateral hypothalamus.

Effect of its stimulation: Eating.

Excessive stimulation → (hyperphagia), i.e. Excessive eating.

Effect of its inhibition: Satiety.

Its destruction produces → Fatal anorexia.

N.B.: This center is tonically active.

It is inhibited transiently by feeding._

2- Satiety center:

Site: In the Ventromedial nuclei of hypothalamus.

Effect of its stimulation→ Satiety (i.e.) aphagia.

Effect of its inhibition → Increase feeding.

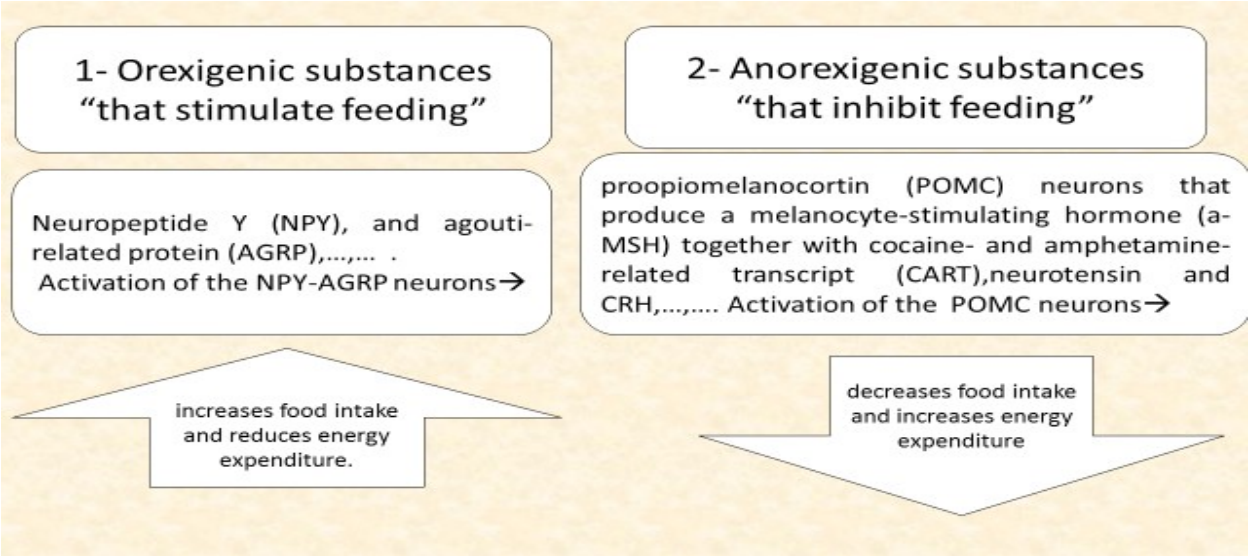
Effect of its destruction → Hyperphagia with extreme obesity.

Amygdloid and prefrontal cortex: - These areas are parts of the limbic system.

Their destruction produces omniphagia, a condition in which the person eats all sorts of food with loss of control on type and quantity of food.

Brain stem centers: -It contains centers that control * Swallowing &* Chewing.

Neurotransmitters and hormones that influence feeding behavior are categorized to:

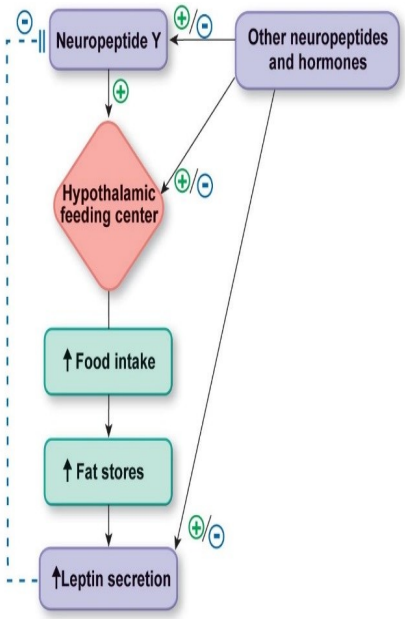


Neurotransmitters and Hormones That Influence Feeding and Satiety Centers in the Hypothalamus

Decrease Feeding (Anorexigenic)	Increase Feeding (Orexigenic)
α-Melanocyte-stimulating hormone (α-MSH)	Neuropeptide Y (NPY)
Leptin	Agouti-related protein (AGRP)
Serotonin	Melanin-concentrating hormone (MCH)
Norepinephrine	Orexins A and B
Corticotropin-releasing hormone	Endorphins
Insulin	Galanin (GAL)
Cholecystokinin (CCK)	Amino acids (glutamate and γ-aminobutyric acid)
Glucagon-like peptide (GLP)	Cortisol
Cocaine- and amphetamineregulated transcript (CART)	Ghrelin
Peptide YY	(PYY) Endocannabinoids

Guyton and Hall "Textbook of Medical Physiology", 12th edition, Chapter 71 Dietary Balances; Regulation of Feeding; Obesity and Starvation; Vitamins and Minerals, unit 13, Table 71-2 Neurotransmitters and Hormones That Influence Feeding and Satiety Centers in the Hypothalamus

Leptin:



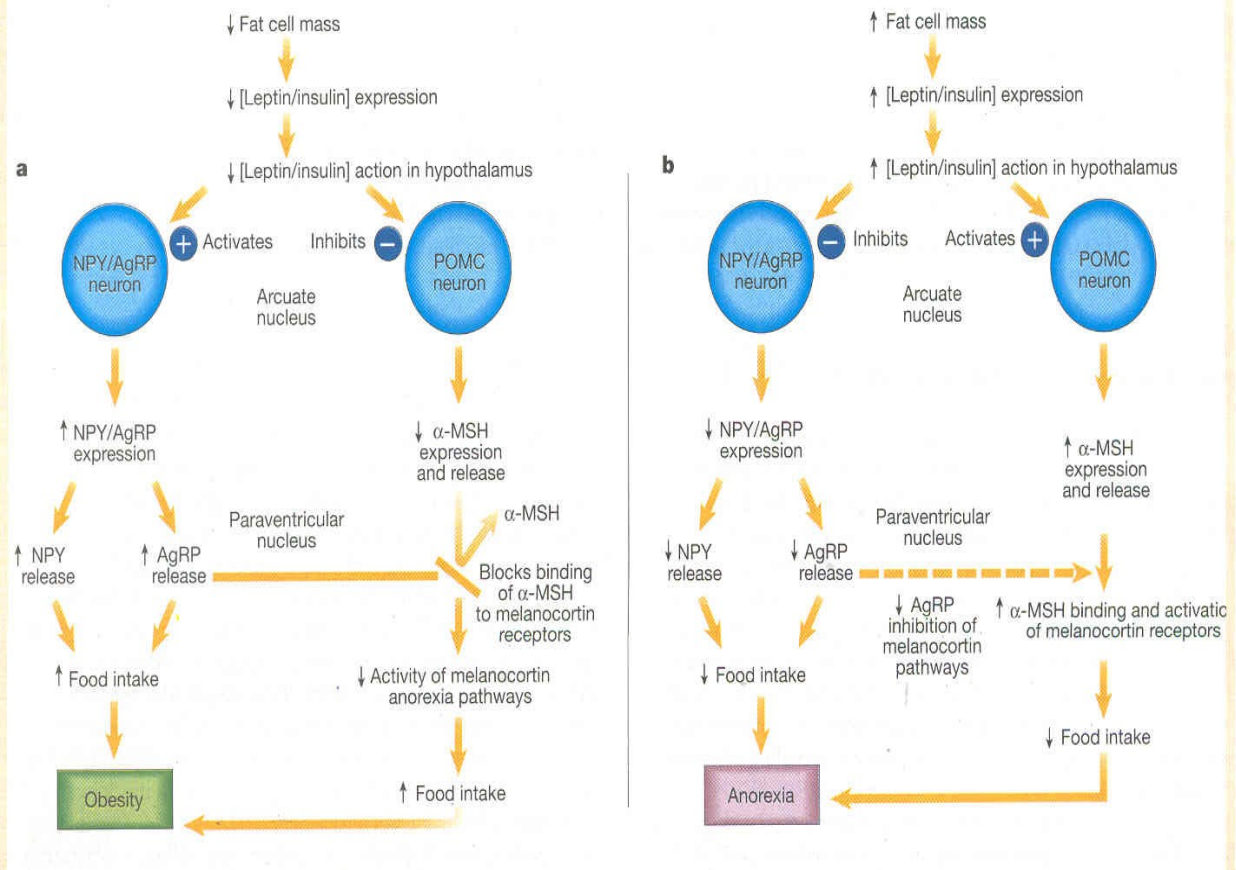
Leptin is a hormone produced by the adipose tissue, which tells the brain about the size of fat stores.

It inhibits the Feeding Center via a negative feedback system to keep body WT constant.

By inhibit the release of Neuropeptide-Y that enhances eating activity.

It also stimulates the metabolic rate and, therefore, plays an important role in the changes in energy expenditure that occur in response to overfeeding or underfeeding.

The neurotransmitters and hormones that influence feeding behavior

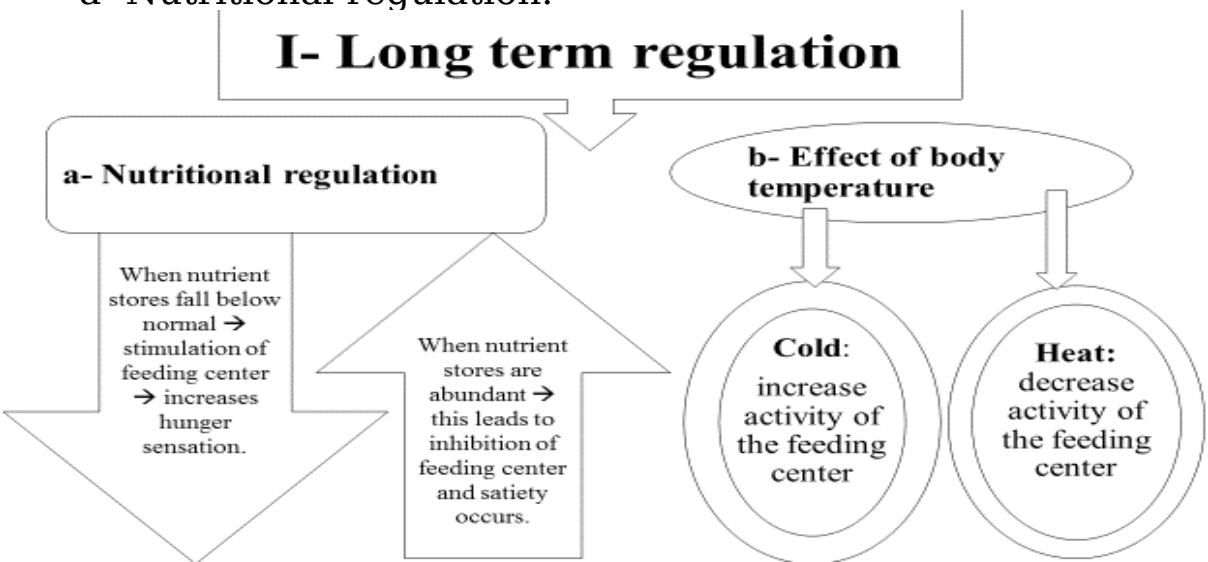


Factors regulating food intake

I- Long term regulation & II- Short term regulation

I- Long term regulation

a- Nutritional regulation.



Glucostatic theory:

The activity of satiety center is determined by rate of glucose utilization within its cells “Cells of the satiety center are sensitive to blood glucose level, or more precisely to the arterio-venous gradient of blood glucose level”:

- High arterio-venous blood glucose gradient at the satiety center → stimulation of satiety center → inhibition of feeding center → anorexia.
- ↑ Increase blood glucose level → ↑ increase activity of satiety center → a sense of satiety.
- Low arterio-venous blood glucose gradient at the satiety center → inhibition of satiety center → release of inhibition of the feeding center → hunger.
- ↓ Decrease blood glucose level → ↑ increase activity of feeding center → feeding sensation.
- That is why, in diabetes, although the blood glucose level is high, the appetite is increased because the arterio-venous gradient is low as the cells cannot use the glucose due to absence of insulin.

Lipostatic and Aminostate theory:

- The activity of satiety center is determined by amount of stored fat in the body.
- It may be also determined by the circulating metabolic products of lipid and amino acids.

II- Short term regulation

The aim of this regulation is to prevent over eating.

The factors responsible for short term regulation are:

1-Alimentary factors:-

A- Gastrointestinal filling: Filling of the stomach and duodenum send inhibitory impulses via vagus to inhibit feeding center.

B- Hormones: release of certain hormones after food intake→ inhibit feeding center, e.g. Cholecystokinin. On the other hand some hormones stimulate feeding center.

C- Other factors such as chewing, tasting and swallowing cause transient inhibition of feeding center which is weak and takes place within (20-40) minutes.

2- Other factors regulate meal quantity & frequency. ≈ causes the person to stop eating

A- Increased MR → raise body temp → (+) satiety center.

B- Increased insulin dependent - glucose utilization→ (+) satiety C.

C- Signals coming from stretch & chemo-receptors in the stomach & duodenum due to presence of food in the GIT.

D- Previous experiences to sight, smell and taste of food affect food intake.

E- Stress is another factor that stimulate food intake via stimulation of hunger sensation.

For reading:

Nature of the different hormones and neurotransmitters regulating food intake:-

CCK, cholecystokinin is a peptide hormone produced in the small intestine in response to feeding. It causes the release of digestive enzymes from the (exocrine) pancreas, bile from the galbladder and release of H+ in parietal cells of the stomach. In the central nervous system it acts as an anorexigen (hunger suppressant).

PYY, peptide tyrosine-tyrosine, released by cells in the ileum and colon in response to feeding and acts as an anorexigen

Insulin, peptide hormone released by β-cells in the islet of Langerhans of the (endocrine) pancreas in response to elevated levels of blood glucose. It acts as an anorexigen.

Leptin, peptide hormone released by adipose tissue in response to triglyceride loading. Leptin.

Ghrelin, is a polypeptide hormone produced by cells lining the fundus of the stomach and by epsilon cells of the pancreas. It has an orexigenic effect (stimulates food intake. It is also produced in the arcuate nucleus where it stimulates secretion of growth hormone by the anterior pituitary gland.

CART, cocaine and amphetamine regulated transcript, propeptide, converted by prohormone convertase into at least two active peptides.

POMC, pro-opiomelanocortin, precursor peptide, converted by prohormone convertases, yielding as many as 10 active peptides amongst which α and β-MSH (melanocortin) & alsoβ-endorphine

NPY, neuropeptide Y, short neuropeptide isolated from the hypothalamus and resembling peptide YY produced by the digestive tract.

AgRP, agouti-related protein, a hormone acts as an antagonist of the melanocortin-3 and -4 receptor (blocks action of α-MSH)

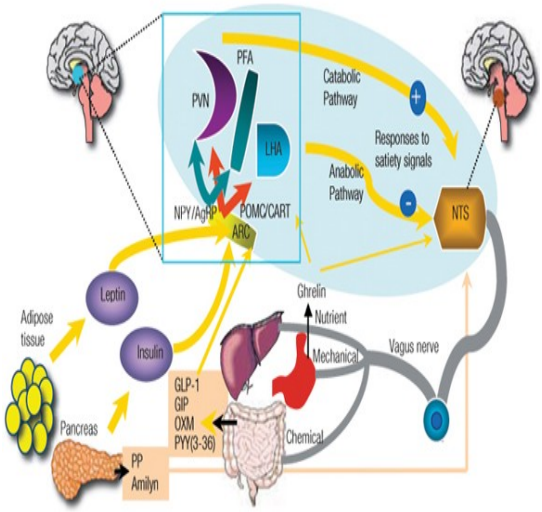


Figure 1. Signals such as leptin and insulin are secreted in proportion to the size of the fat mass and circulate in the blood. They enter the brain and act at the level of the hypothalamus. Neuroendocrine signals from the stomach, the gastrointestinal system and the liver are sent to the hindbrain, providing information about the food that is eaten: its taste and chemical content, and how much the stomach is distended.

Energy homeostasis is maintained by adapting meal size to current energy requirements. This control is achieved by communication between the digestive system and central nervous system (CNS). The status of body energy stores is communicated to the central nervous system by the adiposity-associated hormones leptin, insulin and selected gastrointestinal (GI) peptides, such as ghrelin. Information on meal quality and content is relayed from the gastrointestinal tract to the brain via satiety signals which are primarily integrated by the hypothalamus to determine meals size.

SUGGESTED TEXTBOOKS

1. Ganong's "Review of Medical Physiology", 25th edition, chapter 26, pages 485-487
2. Guyton and Hall "Textbook of Medical Physiology", 12th edition, chapter 71, pages 843-849
3. Sembulingam "Essentials of Medical Physiology", 6th edition, chapter 149, Section 10, pages 858-860